

**REMARKS**

This Preliminary Amendment cancels, without prejudice, claims 1 to 19 in the underlying PCT Application No. PCT/DE02/04536 and adds new claims 20 to 43. The new claims, *inter alia*, conform the claims to United States Patent and Trademark Office rules and do not add new matter to the application.

In accordance with 37 C.F.R. § 1.121(b)(3), the Substitute Specification (including the Abstract, but without the claims) contains no new matter. The amendments reflected in the Substitute Specification (including Abstract) are to conform the Specification and Abstract to United States Patent and Trademark Office rules or to correct informalities. As required by 37 C.F.R. § 1.121(b)(3)(iii) and § 1.125(b)(2), a Marked-Up Version of the Substitute Specification comparing the Specification of record and the Substitute Specification also accompanies this Preliminary Amendment. Approval and entry of the Substitute Specification (including Abstract) is respectfully requested.

The underlying PCT Application No. PCT/DE02/04536 includes an International Search Report, dated May 16, 2003, a copy of which is included. The Search Report includes a list of documents that were considered by the Examiner in the underlying PCT application.

The underlying PCT Application No. PCT/DE02/04536 also includes an International Preliminary Examination Report, dated September 4, 2003, an English-language translation of which is included.

It is asserted that the subject matter of the present application is new, non-obvious, and useful. Prompt consideration and allowance of the application are respectfully requested.

Respectfully Submitted,

KENYON & KENYON

By:   
Richard L. Mayer  
Reg. No. 22,490

One Broadway  
New York, New York 10004  
Telephone: (212) 425-7200  
Facsimile: (212) 425-5288  
**CUSTOMER NO. 26646**

Dated: 12/13/04

## COMPONENT AND METHOD FOR ITS MANUFACTURE

Background InformationFIELD OF THE INVENTION

The present invention relates to a component, ~~in particular~~<sup>e.g.</sup>, a sensor element, having a substrate used as support and a silicon layer, in which the component structure is formed. The component structure includes at least one fixed element, ~~in particular~~<sup>e.g.</sup>, an electrode. Furthermore, the present invention relates to a method for manufacturing such a component.

10

BACKGROUND INFORMATION

In practice, many components and particularly sensor elements having movable structural elements are manufactured from so-called SOI (silicon on insulator) wafers. The structure of an SOI wafer normally includes a monocrystalline silicon layer connected to a silicon substrate via a silicon oxide layer. The component structure is formed in the monocrystalline silicon layer. Movable structural elements are exposed by removing the silicon oxide layer under these structural elements. For this reason, the silicon oxide layer is also called a sacrificial layer. The sacrificial layer is usually removed in an etching process, in which normally other parts of the component structure are undercut as well. This proves problematic in practice, especially with regard to fixed elements of the component structure such as electrodes, for example. That is to say, in sacrificial layer etching, the silicon oxide underneath the electrodes is attacked as well. To date, it is only possible to ensure that the electrodes are mechanically anchored to the silicon substrate if the electrodes have certain minimum dimensions, so that they are

not completely undercut during the etching of the sacrificial layer.

## SUMMARY

### 5 Summary

An example embodiment of the InventionThe present invention provides a ~~concept~~device and method for anchoring fixed structural elements and ~~particularly, e.g.,~~ for anchoring electrodes for components whose component structure is formed 10 in a silicon layer on top of a substrate used as support. This ~~concept is especially~~The foregoing may be suitable for components manufactured from SOI wafers.

According to an exemplary embodiment of the present invention, 15 the fixed element of the component structure ~~is~~may be mechanically connected to the substrate via at least one anchoring element made of an anchoring material and extending through the silicon layer. In the case of an SOI wafer, the anchoring element ~~extends~~may extend through the silicon layer 20 and the sacrificial layer of the SOI wafer. To this end, in the area of the surface of the fixed element, at least one recess ~~is~~may be made in the silicon layer, which extends through the entire silicon layer and the sacrificial layer down to the substrate. The recess ~~is~~may then be filled with an 25 anchoring material, so that the fixed element ~~is~~may be mechanically connected to the substrate via the anchoring element that is thereby created.

According to an exemplary embodiment of the present invention, 30 ~~it was recognized that~~ it is possible to connect fixed elements of the component structure mechanically to the substrate with the aid of anchoring elements. The sole prerequisites for a reliable anchoring are that the anchoring material is of sufficient mechanical strength and is not 35 substantially attacked by the processes used in manufacturing

the component, e.g., by the etching of the sacrificial layer. The anchoring concept according to An exemplary embodiment of the present invention allows may provide for the implementation of the smallest component structures, which are nevertheless may be firmly connected to the substrate, and thus contributes to the miniaturization of components.

Fundamentally, there are various possibilities for implementing a component according to the present invention and for developing and refining the method manufacturing such a component of the present invention.

With regard to miniaturizing the component as much as possible and anchoring it reliably, it proves advantageous to situate the anchoring element may be situated essentially at the center of the surface of the fixed element. To this end, the silicon layer and, in the case of an SOI wafer, the sacrificial layer must may, be patterned accordingly.

Anisotropic etching processes such as trenching, for example, are suitable for patterning the silicon layer, since anisotropic etching processes facilitate the creation of relatively deep yet narrow recesses. In this manner, it is possible to minimize the space required for the component structure. Simply by continuing the anisotropic etching process for patterning the silicon layer, the sacrificial layer ~~can~~may be patterned accordingly. Alternatively, the sacrificial layer may also be patterned using an isotropic etching process, ~~which is especially advantageous with regard to the formation of the anchoring element~~. Namely, during the isotropic etching of the sacrificial layer, the edge region of the recess in the silicon layer is undercut as well. The subsequent filling of the recess extending through the silicon layer and the sacrificial layer produces an anchoring element, which, on account of its barbed structure as well as on account of the enlarged surface connecting it to the substrate, ~~ensures~~may ensure a particularly strong anchoring of the fixed element.

In one advantageous variant of the method according to an exemplary embodiment of the present invention, the anchoring material ~~is~~may be deposited on the silicon layer after the 5 silicon layer and the sacrificial layer have been patterned. This results in the growth of the anchoring material on the substrate in the area of the recess, which fills the recess and forms an anchoring element. In addition, the silicon layer ~~is~~may be coated with anchoring material. Normally, ~~this~~This 10 coating ~~is~~may be at least partially removed again, taking into account the function of the relevant structural elements of the component.

For an anchoring element that is used to anchor an electrode, 15 advantageously an electrically non-conductive anchoring material ~~is~~may be chosen to prevent a short circuit via the substrate of the component. Silicon carbide SiC and especially silicon-rich silicon nitride SiN ~~have proven successful~~may be provided in this regard as anchoring materials. The 20 above-mentioned coating with anchoring material may either extend only over a region of the electrode's surface around the anchoring element or essentially over the entire surface of the electrode. In this case, however, at least one contact hole for the electrode ~~must~~may be formed in the coating. The 25 contact hole ~~is~~advantageously~~may~~ be located outside of the region of the anchoring element, so that the mechanical anchoring of the electrode and its electrical connection are spatially decoupled.

30 A particularly advantageous variant of the component according to ~~In an exemplary embodiment of~~ the present invention features, a cap diaphragm may be formed over the component structure, via which electrical contact ~~is~~may be established with the electrodes of the component structure. The cap 35 diaphragm may also be mechanically connected to the substrate via the anchoring elements.

~~Brief Description of the Drawing~~

As discussed in detail earlier, there are various possibilities for advantageously shaping and refining the teaching of the present invention. For this purpose, reference is made to the claims dependent on the independent claims as well as to the following description of an exemplary embodiment of the present invention based on the drawings.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Fig. 1 shows the perspective representation of a sensor structure according to an exemplary embodiment of the present invention having movable and fixed elements.

Fig. 2 shows a sectional view of the sensor structure represented in Fig. 1 following the application of a second sacrificial layer for producing a cap diaphragm.

Fig. 3 shows the sensor structure represented in Fig. 2 following the patterning of the second sacrificial layer.

Fig. 4 shows the sensor structure represented in Fig. 3 following the application and patterning of a diaphragm layer.

Fig. 5 shows the sensor structure represented in Fig. 4 following the removal of the second sacrificial layer.

#### Description of the Exemplary Embodiment

#### **DETAILED DESCRIPTION**

The An exemplary embodiment for a component according to the present invention represented in the figures is a sensor element 1 for recording accelerations.

Sensor element 1 ~~is~~may be manufactured from an SOI wafer containing a monocrystalline silicon layer 2, which ~~is~~may be connected via a sacrificial layer 3 to a substrate 4, in this

case a silicon substrate. Sacrificial layer 3 ~~is here~~may be a silicon oxide layer. The sensor structure ~~is~~may be formed in monocrystalline silicon layer 2 and ~~includes~~may include movable elements 5, upon which an acceleration may act. The 5 deflections of movable elements 5 from their rest position ~~are~~may be recorded with the aid of electrodes 6, which ~~are~~may be fixed elements of the sensor structure.

According to an exemplary embodiment of the present invention, 10 each electrode 6 ~~is~~may be mechanically connected to substrate 4 via one anchoring element 7. To this end, anchoring elements 7 ~~are~~may be positioned essentially at the center of the respective electrode surface and extend through entire silicon layer 2 and through sacrificial layer 3 down to substrate 4. 15 Anchoring elements 7 ~~are~~may be formed of an electrically non-conductive anchoring material. ~~In the exemplary embodiment described here, silicon-~~Silicon-rich silicon nitride SiN ~~is~~may be used as anchoring material, since it is also resistant to the HF vapor etching of sacrificial layer 3, and since 20 anchoring elements made of SiN are of sufficient mechanical strength.

The production of the sensor structure represented in Fig. 1 beginsmay begin with the creation of the recesses for 25 anchoring elements 7 of electrodes 6 in silicon layer 2. ~~Here, an~~An anisotropic etching process, such as trenching-was, for example, may be used for this purpose. Subsequently, the silicon oxide in the region of these recesses ~~is~~may also removed. ~~In the exemplary embodiment shown here, an~~An 30 anisotropic etching process ~~was~~may also be used for this purpose, since the edge regions of the recesses in silicon layer 2 were not undercut. It ~~should be noted at this point that it~~ is also possible to remove sacrificial layer 3 in the region of the recesses using an isotropic etching process, so 35 that the edge regions of the recesses in silicon layer 2 are

undercut. This variant of the method according to the present invention can be used to may produce anchoring elements that extend in the area of sacrificial layer 3 to below silicon layer 2, thus creating a barbed structure.

5

The recesses, which thenmay extend through entire silicon layer 2 and sacrificial layer 3 down to substrate 4, are nowmay be filled with the anchoring material. For this purpose, SiN ismay be deposited on silicon layer 2 in a deposit step, so that it growsmay grow on substrate 4 in the area of the recesses. A sufficiently largesufficient amount of SiN mustmay be deposited so that the recesses areas to subsequently closedclose the recesses. At the same time, silicon layer 2 ismay be coated with anchoring material. In the exemplary embodiment shown here, this The SiN coating 8 wasmay be patterned in such a way that it remains on the surfaces of the electrodes. The electrically insulating SiN on the surfaces of the electrodes allows for an electrically insulated mechanical connection of the electrodes to a subsequently produced diaphragm layer, which isactuallymay be used for the electrical connection of electrodes 6 of sensor element 1. To allow for an electrical contact between electrodes 6 and a connection in the diaphragm layer, a contact hole 9 ismay be formed for every electrode 6 in corresponding SiN coating 8. Contact opening 9 ismay be located away from the area of anchoring element 7 so as to decouple the electrical contacting and the mechanical anchoring of electrode 6.

30. After anchoring elements 7 have been produced as described above, the functional sensor structure ismay be introduced into silicon layer 2, likewise using an anisotropic etching process, for example, by trenching. In so doing, both movable elements 5 as well as fixed elements of the sensor structure, such as electrodes 6 are6, may be defined. In a further

process step, the etching of the sacrificial layer movable elements 5 ~~are~~may be exposed. To this end, sacrificial layer 3 ~~is~~may be removed not only under movable elements 5, but ~~5 and~~ electrodes 6 are undercut as well. ~~6~~. However, since the 5 anchoring material is resistant to the HF vapor etching used for removing silicon oxide layer 3, electrodes 6 remain mechanically firmly connected to substrate 4 via anchoring elements 7.

10 The electrical connection of electrodes 6 of a sensor element 1, as represented in Fig. 1, may be effected via a thin-film diaphragm, which may additionally also ~~seals~~seal the sensor structure. As an alternative to such thin-film packaging, the 15 electrical connection may also be achieved via a so-called cap diaphragm, which will be explained in more detail below in light of Figures 2 to 4.

To produce a cap diaphragm, a second sacrificial layer 11, which ~~in the present case is also~~may be made of silicon oxide, 20 is applied to the sensor structure depicted in Fig. 1. Second sacrificial layer 11 ~~else~~may close the interstices between individual elements 5 and 6, thereby creating a continuous surface, as shown in Fig. 2.

25 Subsequently, second sacrificial layer 11 ~~is~~may be patterned in such a way that openings 12 and 13 are produced in sacrificial layer 11 wherever the diaphragm layer is to have direct contact with silicon layer 2 (openings 12) or with SiN coating 8 (openings 13). Fig. 3 accordingly shows openings 12 30 in the area of contact holes 9 and openings 13 in the area of the coated surfaces of the electrodes.

A diaphragm layer 14 made of polysilicon or SiGe, for example, ~~is~~may then be produced on top of patterned second sacrificial 35 layer 11. Following the application of a starting layer,

polysilicon may simply be grown epitactically. Subsequently, diaphragm layer 14 ~~is~~may be patterned, which in the case of a polysilicon layer may also be achieved by trench etching. On the one hand, this patterning ~~produces~~may produce openings 15 for the sacrificial layer etching, during which at least second sacrificial layer 11 and possibly also first sacrificial layer 3 may be removed. On the other hand, the patterning of diaphragm layer 14 ~~produces~~may produce openings 16, which electrically insulate the contact lead-throughs between functional silicon layer 2 and diaphragm layer 14 in the area of contact holes 9 from the remaining areas of diaphragm layer 14. These openings 16 are referred to below as insulating trenches. Sensor element 1 featuring the diaphragm layer patterned in this ~~way~~manner is represented in Fig. 4.

15

At this point, second sacrificial layer 11 and, if it has not yet been done, also first sacrificial layer 3 may be removed again, in order to expose movable elements 5 of the sensor structure. HF vapor etching ~~is normally~~may be used for this purpose. As was already mentioned, the anchoring material SiN is not attacked by HF vapor etching, so that electrodes 6 remain mechanically rigidly connected both to substrate 4 as well as to diaphragm layer 14 via anchoring elements 7. Fig. 5 shows sensor element 1 having a cap diaphragm 14 produced in this manner. On the one hand, cap diaphragm 14 is in immediate contact with electrodes 6 via contact holes 9, thus enabling their electrical connection. On the other hand, cap diaphragm 14 is mechanically connected to substrate 4 via SiN coating 8 of the electrode surfaces and via anchoring elements 7, so that cap diaphragm 14 is anchored as well.

30

An electrode 6, electrically connected via cap diaphragm 14, ~~must~~may be separated from the remaining areas of cap diaphragm 14 by an insulating trench 16, in order to achieve the electrical separation of electrode 6. Anchoring element 7

prevents electrode 6 from being completely undercut via insulating trench 16 and other perforations and thus from being detached from substrate 4. Positioning contact hole 9 and anchoring element 7 in different areas of electrode 6  
5 spatially decouples the mechanical anchoring and the electrical connection, so that no complications are to be expected from the insulating trench.

The ~~e~~concept of the present invention for components made from SOI wafers allows foregoing may allow for the mechanical anchoring of fixed structural elements such as electrodes, for example, to the substrate. This is achieved with the aid of anchoring elements which ~~are~~may be introduced into the fixed structural elements and which ~~are~~may be made of a material  
10 resistant to the etching of the sacrificial layer. In the case of an anchoring of electrodes, the anchoring material ~~must~~may also be electrically insulating, in order to allow for a spatial separation of anchoring and electrical contacting.  
15 Silicon-rich nitride or SiC ~~have proven successful~~may be provided as anchoring materials.  
20

Abstract

**ABSTRACT**

The present invention provides a concept **A method and device** are for anchoring fixed structural elements and in particular, 5 **e.g.,** for anchoring electrodes for components, **e.g., SOI wafer** **components,** whose component structure is formed in a silicon layer **{2}** on top of a substrate **{4}** used as support. This concept is especially suitable for components manufactured from SOI wafers. According to the present invention, the **The** 10 fixed element **{6}** **is** **may** **be** mechanically connected to the substrate **{4}** via at least one anchoring element **{7}** made of an anchoring material and extending through the silicon layer **{2}**. In the case of an SOI wafer, the anchoring element **{7}** **extends** **may** **extend** through the silicon layer **{2}** and the 15 sacrificial layer **{3}** of the SOI wafer. To this end, in the area of the surface of the fixed element **{6}**, at least one recess is made in the silicon layer **{2}**, which **extends** **may** **extend** through the entire silicon layer **{2}** and the sacrificial layer **{3}** down to the substrate **{4}**. The recess 20 **is** **may** **then** **be** filled with an anchoring material, so that the fixed element **{6}** is mechanically connected to the substrate **{4}** via the anchoring element **{7}** that is thereby created.

{Fig. 1)}